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ABSTRACT

This document, for secondary school students, is designed to provide an introduction to the effects of pesticides in organisms and the environment. Included are background materials for the teacher, charts and graphs of the effect of chemicals on organisms, questions for discussion and study, and references. (RH)

PESTICIDES AND THE MARINE ENVIRONMENT

A Learning Experience for
Coastal and Oceanic
Awareness Studies

Produced by

MARINE ENVIRONMENT CURRICULUM STUDY
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TITLE: PESTICIDES AND THE MARINE ENVIRONMENT

* CONCEPT: V.B.2.d.(7)

V. The activities of human populations may degrade the environment and restrict the quality of human life.

B. Human activities cause pollution.

2. Pollution reduces the quality and usefulness of the environment.

d. Ecosystems may be altered by pollution.

(7) POLLUTANTS THAT AFFECT PRODUCER ORGANISMS MAY DESTROY THE ENERGY BASE OF THE ECOSYSTEM.

** MARINE CONCEPT: 4.22

4. Man is part of the marine ecosystem.

4.2 Man's activities may deplete and degrade marine ecosystems.

4.22 MAN IS CHANGING MARINE ECOSYSTEMS BY ADDING POLLUTANTS TO AIR AND WATER.

GRADE LEVEL: 7-12

SUBJECT: Biology

CLASS PERIODS: 1-2

AUTHOR: Harry Dillner

OBJECTIVES:

At the completion of this unit, the student will be able to:

1. Design a good experimental procedure to investigate any effects of pesticides on photosynthesis;
2. Interpret graphed data; and
3. Discuss how pesticides may alter photosynthetic activity of aquatic and marine algae, and in turn, how an alteration of photosynthetic activity may affect the food webs of an ecosystem.

* From A Conceptual Scheme for Population-Environment Studies, 1973. Cost $2.50.

** From Marine Environment Proposed Conceptual Scheme, 1973. No charge.

Both conceptual schemes are available from Robert W. Stegner, Population-Environment Curriculum Study, 310 Willard Hall, University of Delaware, Newark, DE 19711.

Teacher Background

THE EFFECT OF PESTICIDES ON PHOTOSYNTHESIS

The photosynthetic activity of green plants produces food for life on earth. A reduction in the total amount of photosynthesis could significantly alter ecosystems. Some recent investigations have shown that pesticides, in particular DDT, can reduce photosynthesis by marine phytoplankton. There are some good reasons for focusing on DDT. It is long-lasting, comparatively easy to detect, widely used, and toxic to a broad spectrum of organisms including man (Woodwell, 1967). A comprehensive discussion of the effects of pesticides on ecosystems may be found in either Epel and Lee (1970), Rudd (1964), or Woodwell (1967).

The first evidence that DDT interfered with photosynthesis appeared in a research paper by Wurster (1968). He tested the effects of DDT on four species of marine phytoplankton from laboratory cultures at Woods Hole Oceanographic Institute and on native phytoplankton communities from Vineyard Sound (Woods Hole). The role of photosynthesis at various concentrations of DDT was measured by uptake of ^{14}C relative to uptake by controls. Concentrations of DDT as low as a few parts per billion in water reduced photosynthesis. Wurster's data are presented in Fig. 1.

Menzel, et al. (1970) did a follow-up of Wurster's experiment and obtained similar results. They found that photosynthesis and growth in cultures of four marine phytoplankton species obtained from different

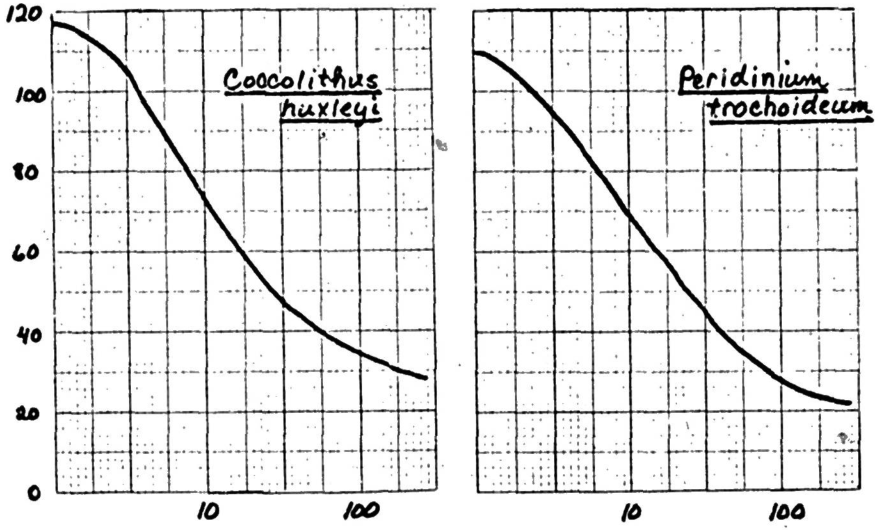
Figure 1

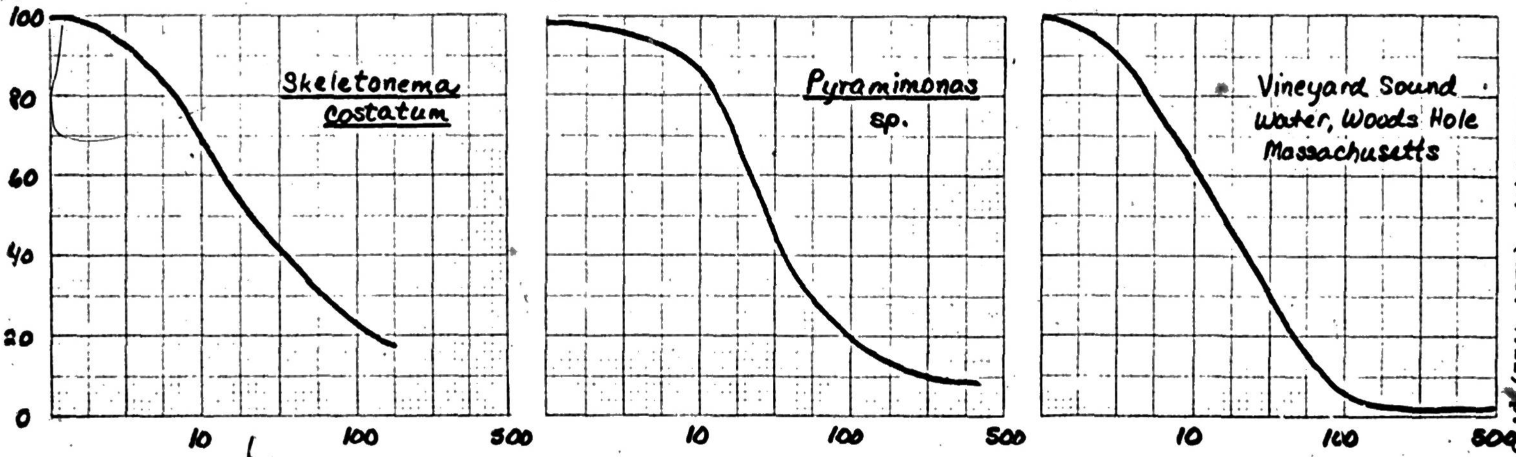
PHOTOSYNTHESIS BY PHYTOPLANKTON AT VARIOUS CONCENTRATIONS OF DDT

measured by uptake of ^{14}C (percentages) relative to uptake by controls

Vertical axes: ^{14}C uptake as % of controls

Horizontal axes: ppb DDT in water





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oceanic environments were affected by DDT, dieldrin, and endrin to varying extents. Effects ranged from complete insensitivity to toxicity at concentrations of 0.1 to 1.0 parts per billion of the pesticides. These data are presented in Figure 2.

Experiments made in 1969 at Hopkins Marine Station in California showed that DDE (a metabolite of DDT) also inhibits photosynthesis and that the inhibition is three times greater than with DDT (Epel and Lee, 1970).

In the three experiments just described, DDT was added to the water in which the plants were being raised; but in actual ecosystems is DDT found in the plant's environment and does it accumulate in plant tissue?

DDT is spread over the earth by wind and water much the same as radioactive fallout. Some of the DDT sprayed from airplanes is circulated through the lower troposphere by air currents and is deposited on the earth by rainfall. Tests in Maine and New Brunswick, where DDT was sprayed from airplanes to control spruce budworm, have shown that 50% of the DDT does not fall to the ground even in open areas. Besides air movements, migrating fish and birds, river runoff, and ocean currents contribute to spreading DDT over the earth (Woodwell, 1967).

Risebrough, et al. (1968) found that the concentrations of chlorinated hydrocarbons in airborne dust carried by the tradewinds from Europe and Africa to Barbados range from less than 1 to 164 ppb. They concluded that the amount of pesticides contributed to the tropical Atlantic by tradewinds is comparable to that which enters the ocean from major river systems.

Evidence exists that antarctic wildlife such as penguins and skuas have body tissue with high DDT concentrations. Obviously this DDT did

Figure 2

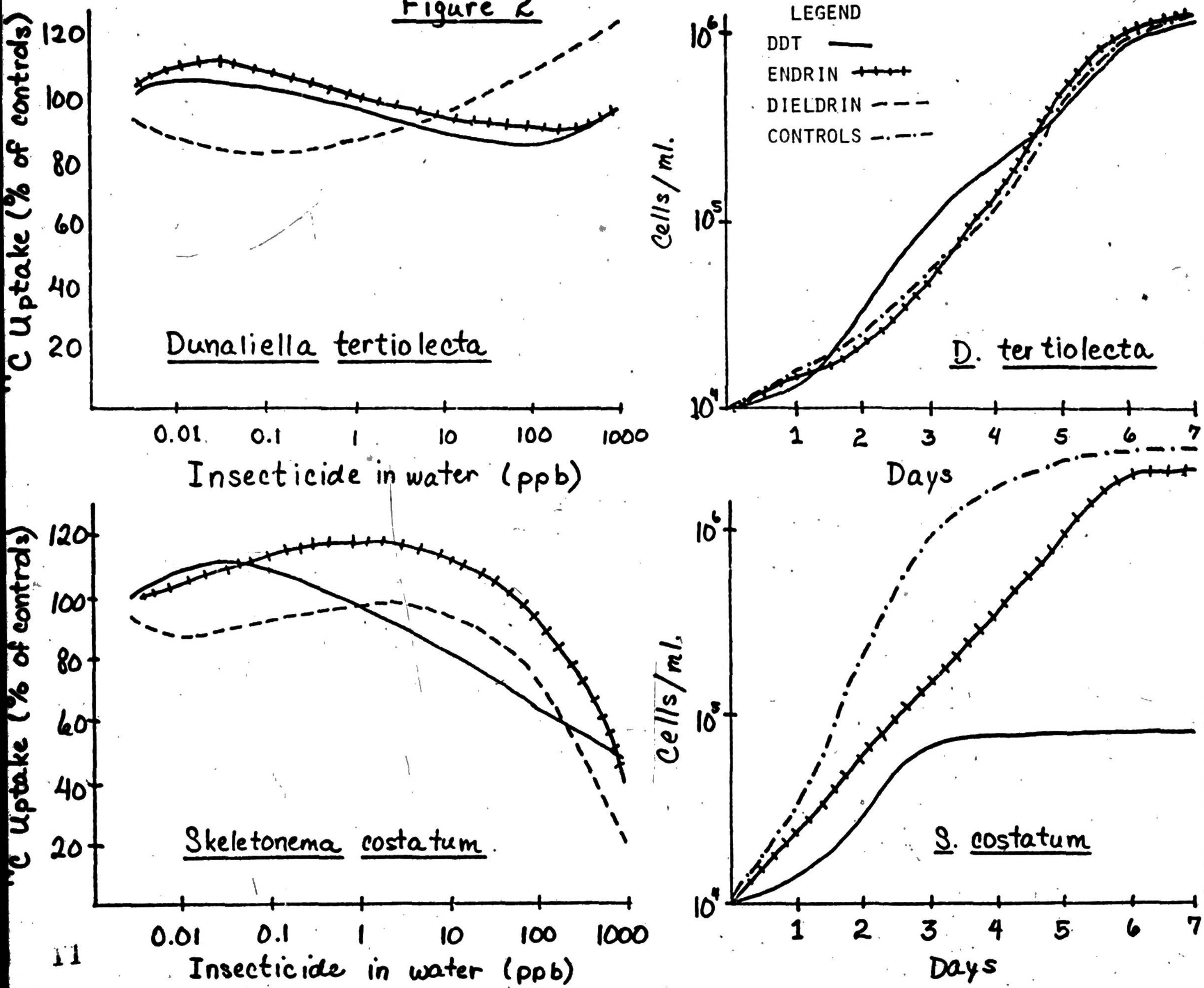
LEFT SIDE OF FIGURE SHOWS ^{14}C UPTAKE BY PHYTOPLANKTON AT VARIOUS CONCENTRATIONS OF DDT (SOLID LINES), DIELDRIN (DASHED LINES), AND ENDRIN (CROSSED LINES) RELATIVE TO UPTAKE BY CONTROLS (PERCENTAGES) ~~OVER~~ 24 HOURS.

LEGEND: DDT ———
ENDRIN ++++
DIELDRIN — — —

RIGHT SIDE OF FIGURE SHOWS GROWTH RATES OF THE SAME SPECIES (CELLS PER MILLILITER) AS A FUNCTION OF TIME WHEN 100 PPB OF DDT (SOLID LINES) AND ENDRIN (CROSSED LINES) WERE ADDED EACH DAY FOR 7 DAYS AND SOLVENT WAS ADDED IN EQUAL VOLUME TO THE CONTROLS (DOT-DASH LINES).

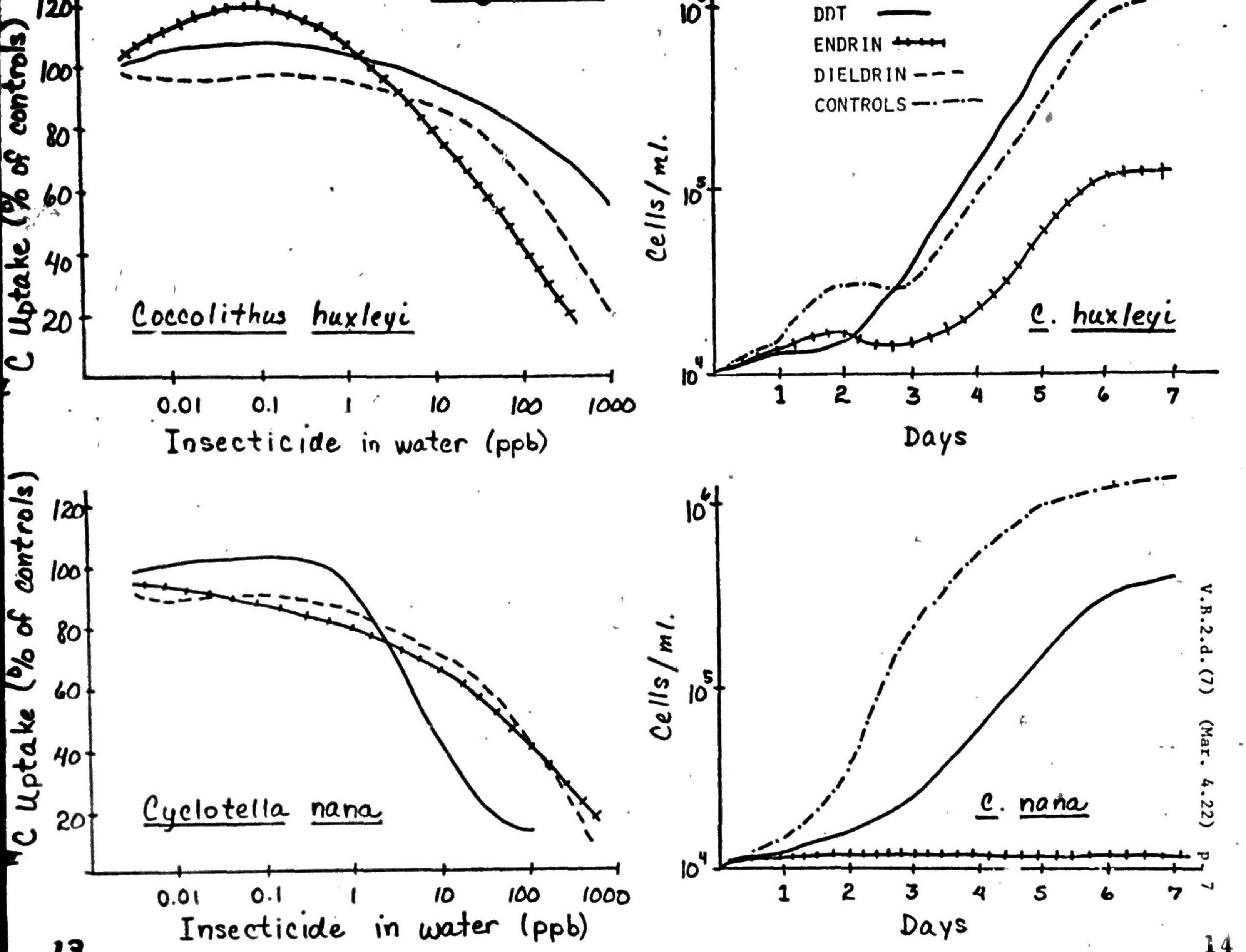
LEGEND: DDT ———
ENDRIN +++
CONTROLS —•—•

Figure 2



LEGEND
DDT
ENDRIN
DIELDRIN
CONTROLS
¹⁴C Uptake (% of controls)
120
100
80
60
40
20
0.01
0.1
1
10
100
1000
Insecticide in water (ppb)
Dunaliella tertiolecta
Skeletonema costatum
Cells/ml.
10⁶
10⁵
10⁴
1
2
3
4
5
6
7
Days
D. tertiolecta
S. costatum

Figure 2



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not originate in the immediate environment of these animals, but was carried there by some means (Tatton and Ruzicka, 1967).

Various studies indicate that DDT accumulates in plant tissues. In an investigation of Long Island Estuary and along the nearby shore, Cladophora was found with 0.08 ppm DDT residues and the shoots of marsh plants had 0.33 ppm DDT residues, while the roots of these plants had 2.80 ppm DDT residues (Woodwell, 1967). In an Ohio marsh DDT was concentrated 3,000 times in algae within three days of application (Rudd, 1971). In a salt marsh bordering Long Island Sound, plankton (mostly zooplankton) had 0.04 ppm DDT residues while the water contained 0.00005 ppm DDT residues (Woodwell, Wurster, and Isaacson, 1967).

The following data from Butler (1962) show the highest concentration of insecticides tolerated by five kinds of phytoplankton used by molluscan larvae as food:

Sevin	100 ppb.
Lindane	500 ppb.
DDT	1,000 ppb.
Dipterex	10,000 ppb.

Cope (1961) describes a DDT spraying program to control spruce budworm in Yellowstone River drainage in Yellowstone National Park. 71,678 acres were sprayed by aircraft with 1 lb. per acre. 0.18 lb per acre reached the ground. Three samples of Potamogeton, an aquatic plant, were analyzed for DDT. All contained greater concentrations than the water samples taken from the same locations. These data can be found in Figure 3.

It is difficult to evaluate the effects of DDT on photosynthesis. There are sufficient data indicating that DDT accumulates in plant tissue, but only a few studies show that DDT interferes with photosynthesis, and these studies are confined only to marine phytoplankton. No similar studies

FIGURE 3

DDT CONTENT OF THE AQUATIC PLANT, POTAMOGETON

Yellowstone Collecting Site	Days After Exposure	DDT Content (ppm)	Highest DDT Content Found in Water (ppm)
Lamar River	15	1.7	0.03
Slough Creek	15	2.3	None detectable
Yellowstone River	16	0.8	0.01

have been performed on terrestrial plants. It is readily apparent that more research needs to be conducted to determine if DDT and other toxic chemicals affect photosynthesis in all types of plant life.

Ehrlich and Ehrlich (1970) assess some of the possible alterations to marine ecosystems that could be initiated by the toxic effect of DDT on phytoplankton. They reason that qualitative changes in phytoplankton communities are more probable than large quantitative changes. Since phytoplankton populations are differentially susceptible to DDT, shifts in dominant species could lead to blooms of one or a few species. These shifts would have serious consequences throughout food webs. It is possible that phytoplankton not normally eaten by large herbivores would predominate, thus eliminating many larger animals. Such a shortening of food chains could leave man with only microscopic plants and animals as food sources from the sea. It is also possible that phytoplankton populations near the shore could become dominated by smaller species. Such a shift would lengthen food chains and reduce fish populations at the upper trophic levels.

In summary, the alarm has been sounded concerning the effects of DDT on photosynthesis. Only more research will give us a better basis for analyzing this potential problem. The outcome is of paramount importance since life on earth is dependent upon basic food production by green plants.

THE EFFECT OF PESTICIDES ON PHOTOSYNTHESIS

Before beginning this lesson, students should have a general knowledge of toxic substances, especially pesticides, which are discharged into the environment. In particular, students should be aware of the multiplying effect of DDT in food chains, and the physiological effects of DDT on individual organisms.

This inquiry on the possible effects of pesticides on photosynthesis is conducted by asking students the following questions:

1. <u>How could it be determined if pesticides interfere with photosynthesis?</u>

   Students are to suggest an experimental procedure that will yield evidence to answer this question. This is a "dry lab" in that students do not conduct an actual experiment, but only suggest a possible procedure. Developing a procedure should involve answering the following questions:

   <u>a.</u> What kinds of plants should be used?

   Aquatic or marine plants would be better than terrestrial plants because the application of a pesticide to a water medium could be more easily controlled. If microscopic algae are used, data on large populations can be obtained in a relatively short period of time.

   <u>b.</u> What pesticide should be chosen?

   DDT is a logical choice. It is long-lasting, comparatively easy to detect, widely used, and toxic to a broad spectrum of organisms, including man (Woodwell, 1967).

   <u>c.</u> How could it be determined if the plants are being affected?

   Measurements could be made of longevity, growth rate, reproductive rate, and rate of photosynthesis. The rate of photo-

synthesis could be determined by measuring CO_2 uptake or carbon and oxygen production. A control is necessary.

2. What is indicated by the graphs on Figure 1?

These graphs show data from an experiment on the effects of DDT on photosynthesis by marine phytoplankton. Students should see that ^{14}C uptake, which is an indicator of photosynthesis, decreased as the concentration of DDT increased (Wurster, 1968).

3. What questions should be asked about the effects of DDT in natural marine ecosystems?

Students should determine that answers to the following questions are necessary:

a. Do marine phytoplankton live in an environment containing DDT?

b. Do plants absorb DDT from their natural environment?

c. How is DDT dispersed in the marine environment?

d. How might DDT alter marine ecosystems?

Answers to each of these questions are to be discussed during the remainder of the inquiry.

4. Do marine phytoplankton live in an environment containing DDT?

Yes, as an example, water in a salt marsh bordering Long Island Sound was found to contain 0.00005 ppm DDT residues (Woodwell, Wurster and Isaacson, 1967).

5. Do plants absorb DDT from their natural environment?

Display Figure 3 which lists the concentration of DDT in an aquatic plant following the spraying of DDT to control spruce budworm in Yellowstone National Park in 1957. DDT content in

all three samples is higher than the concentration of DDT in the water (Cope, 1961). Other data can be presented. In studies in the Long Island area, Cladophora contained 0.08 ppm DDT residues and the shoots of marsh plants had 0.33 ppm DDT while the roots of these plants had 2.80 ppm DDT. Plankton (mostly zooplankton) had 0.04 ppm DDT residues while the water contained 0.00005 ppm DDT residues (Woodwell, 1967)(Woodwell, Wurster and Isaacson, 1967).

6. How is DDT dispersed in the marine environment?
   Air and ocean currents, rainfall, river runoff and migrating fish and birds disperse DDT. Birds of the antarctic such as penguins and skuas contain high concentrations of DDT even though they live far from areas where DDT has been sprayed (Woodwell, 1967; Tatton and Ruzicka, 1967; Risebrough, et al., 1968).

7. How might DDT alter marine ecosystems? Display Figure 2 which shows the effect of DDT on growth rates in phytoplankton. Students should see that Lunaiiella is not affected by DDT, but Skeletonema is greatly affected. Students should conclude that various species are differentially affected by DDT. This is significant because changes in species composition would cause a shift in dominant species which could alter food webs. Such a qualitative change is more likely to occur than a quantitative change in total photosynthetic activity (Menzel, Anderson and Randtke, 1970; Ehrlich and Ehrlich, 1970).

8. Why is it of paramount importance that further research be conducted on the effects of DDT and other toxic chemicals on photosynthesis?

Little is known about the toxic effects of various pollutants on photosynthesis. A few experiments provide substantial evidence that phytoplankton is affected, but there is no clear evidence that terrestrial plants are affected. Since the amount and variety of pollutants is increasing rapidly, it is essential that we know their effects on so vital a process as basic food production.

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